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Ornamental plantings of *Arbutus unedo* L. facilitate colonisations by *Charaxes jasius* (Linnaeus, 1767) in Madrid province, central Spain

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Abstract. The distribution of butterfly species is limited by availability of larval host plants growing in suitable climatic conditions. The Two-tailed Pasha, *Charaxes jasius* (Linnaeus, 1767), is a Mediterranean butterfly with only sporadic historical records in Madrid, Spain's most central province, where the host plant is uncommon and winters are colder than in most parts of the butterfly's range. We show the first evidence of juvenile stages of the species in two towns of north-central Madrid and compile records of *C. jasius* from Madrid over the past four decades. Our results suggest that, in the absence of widespread host plants, *C. jasius* is using suburban ornamental plantings of its host plant to colonise a region which may be becoming more climatically suitable.

Introduction

The Two-tailed Pasha, *Charaxes jasius* (Linnaeus, 1767) (Lepidoptera: Nymphalidae: Charaxinae), has been reported from regions of mainly coastal Mediterranean or Atlantic climates (Kudrna et al. 2015; GBIF 2017). The species' distribution follows the native range of its main larval host plant, the Strawberry-tree (*Arbutus unedo* Linnaeus), that typically grows in coastal and inland areas with mild climates (Torres et al. 2002).

In the Iberian Peninsula, both the butterfly and its host plant occur mainly in areas of non-continental climate, with the exception of some occasional records of the adult butterfly in inland thermal refuges (Domínguez and Martínez 1993; García-Barros et al. 2004; Molina et al. 2011; García-Barros et al. 2013). In central Spain, *C. jasius* is reported to have settled in the southwestern extreme of Madrid province (Vicente Arranz and García-Carrillo 2009), corresponding to a small remnant population of Strawberry-trees (Domínguez and Martínez 1993; Baonza-Díaz 2001), closer to the stronghold of the butterfly, further to the west in the provinces of Cáceres and Toledo (García-Barros et al. 2004). Strawberry-trees are also grown ornamentally, and can be found throughout Madrid, thus presenting opportunities for *C. jasius* to expand its distribution to areas having more continental conditions.

This study was motivated by the unexpected sighting of an adult *C. jasius* in central Spain, in a north-central town of Madrid province, Colmenar Viejo, situated approximately 80 km from the species' southwestern stronghold (Vicente Arranz and García-Carrillo 2009). This led us to investigate whether the butterfly is breeding in the area, and if it is making use of ornamental Strawberry-trees

to expand from its southwestern settlement to more northern and central areas. To answer these questions, we carried out (i) a search and created a list of Strawberry-trees present in the town of Colmenar Viejo and in some neighbouring localities, looking for evidence of the butterfly's presence, and (ii) compiled a list of existing information on the distribution of the butterfly in Madrid province.

Material and methods

Evidence for colonisation of north and central Madrid

Following the sighting of an adult *C. jasius* in Colmenar Viejo on 12.ix.2017, an inventory of the ornamental Strawberry-trees present in this locality was carried out. The trees were then searched for the presence of *C. jasius* (eggs, larvae and/or adults). In addition, the neighbouring localities of Hoyo de Manzanares, Tres Cantos, Cantoblanco and San Agustín del Guadalix, situated west, south and east of Colmenar Viejo, were also searched. We selected these adjacent localities, as we expected that they would form part of the most likely approach of the butterfly from its southwestern settlement.

A total of 298 ornamental trees, found largely in urban parks and gardens across the five localities, were searched from mid-September to late October 2017, at the end of the summer generation of the butterfly. Seventy-one of the trees were located in Colmenar Viejo, while 201 trees were located in Tres Cantos, 7 in Cantoblanco, 4 in San Agustín del Guadalix and 15 in Hoyo de Manzanares.

Review of prior records

Information on the butterfly's distribution in Madrid province was reviewed using records from the following sources: Gómez Bustillo and Fernández-Rubio 1974; Martínez and Casado 1984; Simón 1986; Gómez de Aizpúrua 1987, 1997; Gómez de Aizpúrua et al. 1999, 2009; Vicente Arranz and García Carrillo 2009; Cobo 2013; García Carrillo et al. 2015. For each source, the locality name, geographic coordinates, observer name and development stage found (egg, larva and/or adult) were compiled into a table.

Results

Two butterflies, 25 eggs and one larva were found during the searches of the ornamental Strawberry-trees. Both butterflies, 21 eggs and the larva were found across the town of Colmenar Viejo, while the remaining four eggs were observed on three trees in Tres Cantos, south of Colmenar Viejo (Table 1). No evidence of the butterfly's presence was found in the three remaining localities, where only a small number of trees was located and searched (Table 1).

The review of prior distribution records spanned the past four decades, and revealed a number of sporadic observations which, like that at Colmenar Viejo, are located far from the butterfly's southwestern range (Table 2; Fig. 1). The majority of the records from the last 10 years were obtained in west and north-central localities of the province, closer to the Guadarrama mountain range, while the older records were generally found further south (Fig. 1). The two most northern records in the province constituted the two most recent sightings of the butterfly (Table 2; Fig. 1). The northernmost record, from Miraflores de la Sierra, was obtained approximately 15 km from one of the few relict populations of indigenous Strawberry-trees in the country (Molina et al. 2011; Bernal González 2012; García Carrillo et al. 2015), while the second-most northern record, from El Escorial, was obtained in an urbanization with numerous ornamental plantings (García Carrillo et al. 2015). The

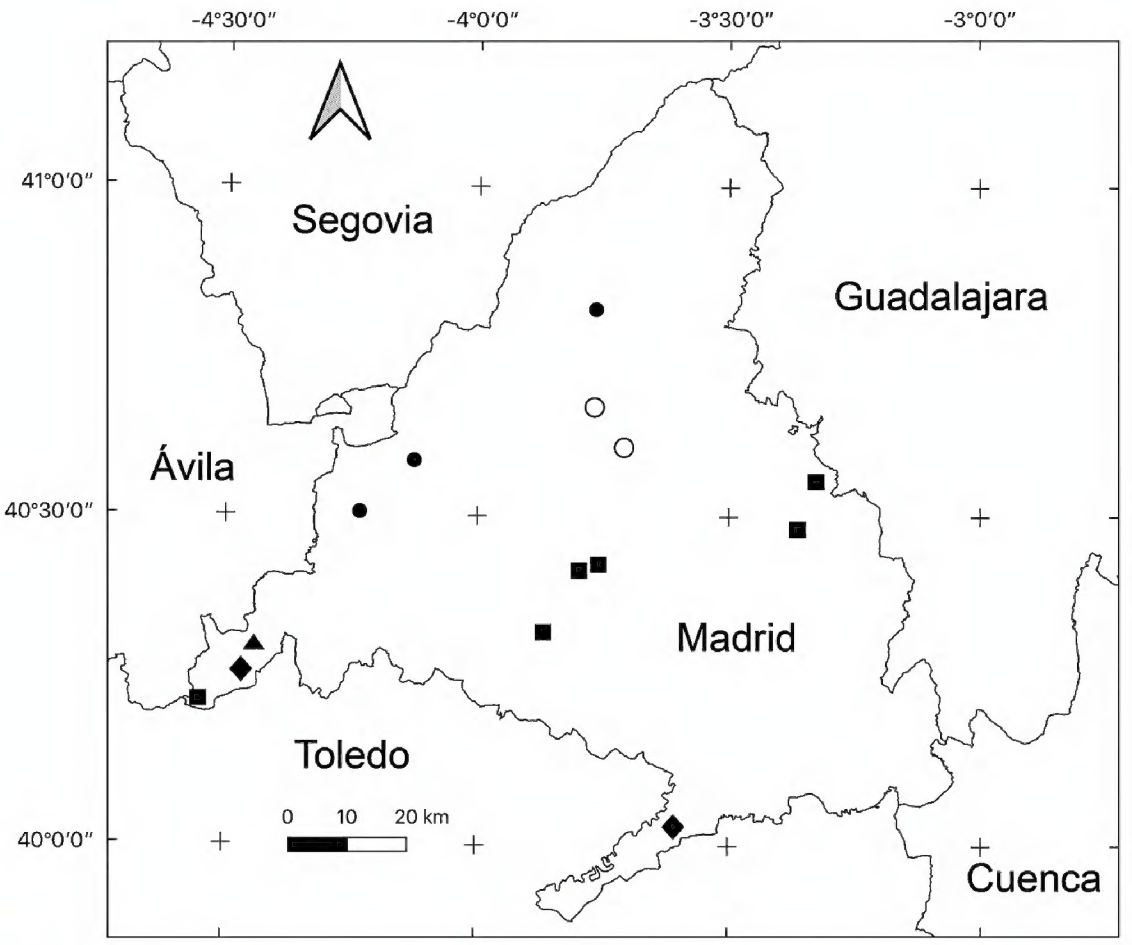

Figure 1. Map of the localities of Madrid province (central Spain) where *C. jasius* has been observed. Squares indicate records from 1980 to 1989, triangles from 1990 to 1999, diamonds from 2000 to 2009 and circles from 2010 to 2017 (see Table 2). White circles indicate both new records provided in this study (see Table 1).

Table 1. List of the localities in Madrid province where Strawberry-trees were examined for the presence of *C. jasius*. The geographical coordinates, number of trees searched and development stage found are also provided.

Locality	Geographical Coordinates	Number trees	Development stage
Colmenar Viejo	40°40'00.2"N, 3°46'17.5"W	–	1 adult
	40°39'57.9"N, 3°46'09.5"W	1	5 eggs, 1 larva
	40°39'49.7"N, 3°46'21.8"W	1	7 eggs
	40°39'11.5"N, 3°46'19.2"W	15	2 eggs
	40°39'40.0"N, 3°45'44.8"W	5	–
	40°39'59.5"N, 3°46'31.0"W	3	–
	40°40'06.5"N, 3°46'30.6"W	3	–
	40°40'05.0"N, 3°46'29.0"W	2	–
	40°39'31.7"N, 3°45'45.7"W	2	–
	40°40'04.4"N, 3°45'56.0"W	1	–
	40°39'48.1"N, 3°45'54.6"W	1	–
	40°40'10.1"N, 3°46'35.3"W	3	–
	40°39'15.1"N, 3°46'32.2"W	20	7 eggs
	40°40'07.6"N, 3°46'38.2"W	1	–
	40°39'36.0"N, 3°45'41.2"W	5	–
	40°39'55.0"N, 3°46'11.6"W	1	–
	40°39'41.7"N, 3°45'54.6"W	–	1 adult
	40°39'33.1"N, 3°45'24.7"W	7	–
Tres Cantos	40°36'18.3"N, 3°42'33.6"W	120	2 eggs
	40°35'44.0"N, 3°42'22.8"W	1	1 eggs
	40°36'30.9"N, 3°42'27.8"W	80	1 eggs
Cantoblanco	40°32'37.7"N, 3°41'42.8"W	4	–
	40°32'30.1"N, 3°41'25.9"W	3	–
San Agustín del Guadalix	40°40'53.3"N, 3°36'49.0"W	4	–
Hoyo de Manzanares	40°37'26.9"N, 3°54'16.9"W	15	–

Table 2. List of the localities in Madrid province where *C. jasius* has previously been observed. The geographic coordinates (Geo. coord.), 10×10 km MGRS grid references (MGRS), development stage (Dev. stage), date, observer name (Observ.) and source of each record are also provided.

Locality	Geo. coord	MGRS	Dev. stage	Date	Observ.	Source
Meco	40°33'16.1"N, 3°19'45.9"W	30TVK78	Adult	1974, 1999	J. Álvarez	Gómez Bustillo and Fernández-Rubio 1974; Gómez de Aizpúrua et al. 1999
Móstoles	40°19'25.0"N, 3°51'54.3"W	30TVK26	Adult	IX-1984	–	Martínez and Casado 1984
Sierra de la Higuera	40°13'03.2"N, 4°34'42.2"W	30TUK65	Adult	IX-1984	M.A. Martínez and F. Casado	Martínez and Casado 1984
Casa de Campo	40°25'20.7"N, 3°45'19.0"W	30TVK37	Adult	12-VI-1982	L.A. Rovenga	Simón 1986
Somosaguas	40°25'07.1"N, 3°47'48.5"W	30TVK37	Adult	IX-1984	F. Rodríguez	Simón 1986
Alcalá de Henares	40°28'57.5"N, 3°21'57.0"W	30TVK78	Adult	1987	C. Gómez et al.	Gómez de Aizpúrua 1987a
Cadalso de los Vidrios	40°18'07.3"N, 4°26'43.4"W	30TUK75	Adult	1997	C. Gómez de Aizpúrua	Gómez de Aizpúrua 1997
Aranjuez	40°01'50.9"N, 3°36'19.6"W	30TVK43	Adult	2009	C. Gómez de Aizpúrua	Gómez de Aizpúrua et al. 2009
Cenicientos	40°15'45.6"N, 4°27'57.0"W	30TUK65	Adult	2009	J.C. Vicente and A. García Carrillo	Vicente and García Carrillo 2009
Cadalso de los Vidrios	40°18'07.3"N, 4°26'43.4"W	30TUK75	Adult	2009	J.C. Vicente and A. García Carrillo	Vicente and García Carrillo 2009
Robledo de Chavela	40°30'16.9"N, 4°14'08.8"W	30TUK98	Larva	14-I-2012	A. Cobo	Cobo 2013
El Escorial	40°34'58.7"N, 4°07'41.0"W	30TVK09	Adult	1-VII-2015	R. de la Peña	García Carrillo et al. 2015
Miraflores de la Sierra	40°48'42.1"N, 3°45'58.1"W	30TVL32	Adult	21-VI-2015	K. Leahy	García Carrillo et al. 2015

majority of the records collected were observations of adult butterflies, although a larva had been detected in the west-central locality of Robledo de Chavela in 2013 (Cobo 2013) (Table 2; Fig. 1).

Discussion

Our findings of a small number of juvenile stages of *C. jasius* in two north-central localities of Madrid province suggest that a small breeding population occurs in the area. Furthermore, the existence of prior records in localities that are very distant from the butterfly's southwestern settlement, and where Strawberry-trees do not naturally grow, supports the possibility that the highly mobile *C. jasius* is using ornamental trees to colonise new areas.

Ornamental plantings of larval host plants have been found to play an important role in the expansion of other butterfly species, such as the Common Brimstone, *Gonepteryx rhamni* (Linnaeus, 1758), that has spread along plantings of Alder Buckthorn (*Frangula alnus* Mill.) on roadsides in North Wales (Gutiérrez and Thomas 2000). Breeding populations of the American Monarch, *Danaus plexippus* (Linnaeus, 1758), have been observed in the Azores islands following the introduction of the Swan Milkweed (*Gomphocarpus fruticosus* (L.) W.T. Aiton) for ornamental purposes (Neves et al. 2001). Similarly, Cycadians (genus *Eumaeus* Hübner, 1819) have been reported to follow and use ornamental cycads in Xalapa (Mexico) and Southeast Florida (USA) (Ramírez-Restrepo et al. 2017).

However, although ornamental Strawberry-trees have been present in the town of Colmenar Viejo for 30–40 years (Robert Wilson, pers. comm.), *C. jasius* has only now been recorded there.

This could be a result of the species not being surveyed in that locality before. However, extensive butterfly surveys have previously been conducted across north-central Madrid (Gómez de Aizpúrua 1987, 1997; Vicente Arranz and García Carrillo 2009), yielding only two records of *C. jasius* to date, both of which were adult individuals observed within the last five years (see Table 2). Given our additional observation of a small breeding population in an area where the winters are colder than in most parts of the butterfly's range, and the scarcity of north-central records until recent years, we believe that warming temperatures may be enabling the butterfly to colonise the ornamental trees and disperse under more continental conditions.

Conclusions

Our study extends previous findings on the importance of ornamental host plants for the expansion of butterfly species, showing that *C. jasius* may be using ornamental Strawberry-trees to colonise new areas in central Spain. We also postulate that the butterfly is able to progress under these continental conditions as the region becomes climatically more suitable. Nevertheless, additional sampling should be conducted in spring, to determine whether the butterfly is successfully overwintering in the area, together with an extensive network of surveys across the province, to understand if warming climate conditions are actually playing a role in the butterfly's expansion.

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